APPLIED SCIENCE

INCORPORATED WITH

TRANSACTIONS *of the* UNIVERSITY *of* TORONTO ENGINEERING SOCIETY

Vol. VIII - New Series

May, 1913 to April, 1914

PUBLISHED BY
THE UNIVERSITY OF TORONTO ENGINEERING SOCIETY
ENGINEERING BUILDING
UNIVERSITY OF TORONTO, CANADA

Applied Science

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Old Series Vol. 26 TORONTO, FEB. 1914 New Series Vol. VIII. No. 10

STANDARDIZING METHODS OF TRANSFERRING SKILL*

By Frank B. Gilbreth, C.E.

A "lost art" is one that has been superseded by another art.

Skill in making and hardening copper tools was gradually lost by the advent of superior tools of steel. In many arts the practice of but few years ago is now obsolete, and almost yearly, new advances in tool steel making and hardening are causing the comparatively recent processes to go the way of their lost and abandoned predecessors.

These continued cycles of improving, superseding, and abandoning are usually caused by reason of a better material supplanting.

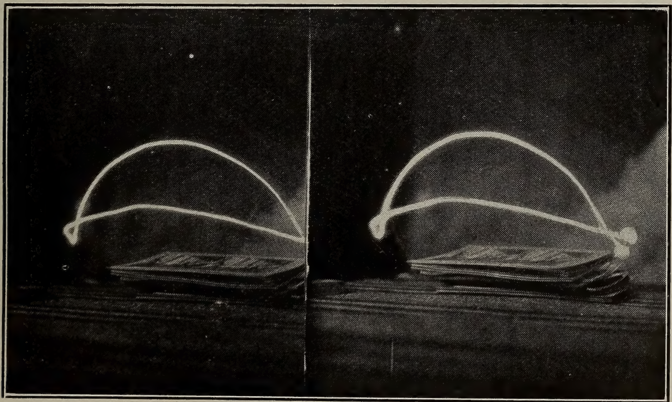


Fig. 1

The better material causes financial gain and dissemination of knowledge regarding the value of the material. This is almost invariably true, of an improved **material,** because a **material** remains, and is something clearly visible and easily measured. On the other hand, a **"method"** is much less tangible and therefore harder to visualize,

*From a lecture delivered before the University of Toronto Engineering Society, Nov., 1913

harder to measure, and harder to capture, record, and circumscribe, and until the introduction of the micro-motion and cyclegraph process, the merit and efficiency of a method was no longer visible after the operation was completed. Hence, a "lost method" is a very common thing.

It is not strange that the transference of skill of manual methods has been much slower than the dissemination of knowledge about

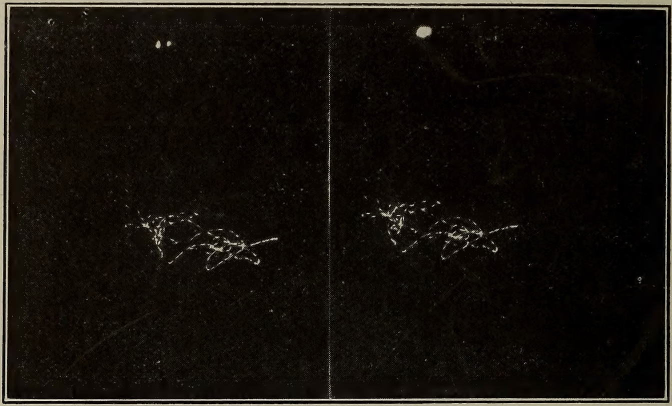


Fig. 2

materials, and there are other reasons besides, that have hindered the transference of skill to fellow workers.

Again, it has been most difficult to record data of skill in such a way that they could be used efficiently for self-teaching by the workers of posterity who at best must do without the feature of "demonstration." "Cold data," or data recorded by one person and used without assistance or oral explanation and demonstration by another, is apt to lack clearness and to be ambiguous.

There are also other difficulties in transferring skill not generally recognized, such as the fact that cycles of slow motions cannot be made like those of fast motions, on account of the effects of the interference of habit, centrifugal and centripetal forces, combinations of motions, automaticity, the location of natural rest periods in the cycles, and other reasons.

The purpose of this paper is to present two measuring methods that will record data in such manner that the data can be used at any time for teaching inexperienced beginners as well as experts at the particular work recorded.

The measuring methods shown herein have been named Micro-Motion Study and Chronocyclegraphology, and they are accomplished principally, but not wholly by two sets of apparatus: (1) a cinematograph photographing a fast revolving hand of a clock accompanying the workers' manual motions, and (2) a chronocyclegraph apparatus that records a simultaneous recapitulation of all of the workers motions, and at the same time records the orbits or

paths of the motions in one, two or three dimensions, as desired, with the direction, elapsed time, relative time, speed, relative speed, and the still or resting points, habit, mental inertia, mental hesitation, and other human characteristics.

With these devices and methods, their advocators have doubled, tripled, and in some cases, more than quadrupled the output of workers, and at the same time diminished the amount of fatigue of the day's work.

These devices record with great accuracy the performance of the most skilled with such clearness that the skill, advantages, and economics of the complete method is conserved for the present and succeeding generations.

The accompanying illustrations are taken from experiments in Mr. Gilbreth's and in his clients' laboratories, and on actual work.

Fig. 1 is a cyclegraph of a single cycle in the operation of sorting photographs. Note the springing up of the line at the left hand side of the picture where the hand has dropped the photograph. Note also that the cyclegraph is a continuous line.

Fig. 2 is a stereoscopic chronocyclegraph showing excellent motions used in a simple operation in folding cotton cloth.

Fig. 3 represents a demonstration of the chronocyclegraph. The operation depicted is that of reaching for a telephone and a piece of paper simultaneously to write down a message. Note that the pointed end of each flash shows the direction of each motion, and that

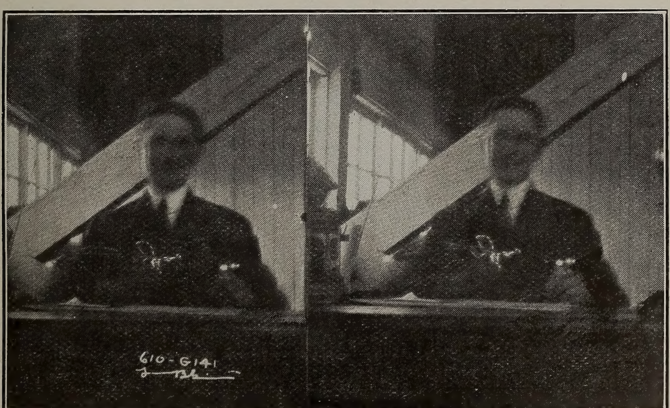


Fig. 3

the time between the flashes can be determined by measuring the distance between centres.

Fig. 4 is a typical motion picture showing standardized method of assembling a braider, with the standard packet and assembly table.

These motion pictures are not intended, primarily, either to be thrown upon the screen or to be printed, but are intended to be studied on the film.

Mr. Gilbreth has given a great deal of his time to the establishment at Providence, R. I., of a permanent museum for the collection and exhibition of devices for the elimination of unnecessary fatigue of the worker. He has, during the last few years, devoted most of his time to the introduction of systems of industrial management and to motion study and is thoroughly convinced that the horrors of over-fatigue in factories are more terrible than the horrors

Fig. 4

of accident and death. The purpose of the present movement is to encourage a permanent exhibit in the interests of the comfort of the working people. Last August Mr. Gilbreth conducted a summer school in Providence where he had the co-operation of professors and instructors from colleges and other institutions of learning. The movement is worthy of the attention of all employers, especially manufacturers, as it will in all probability ultimately result in greater returns for the employer and at the same time, less fatigue for the employed.

H. V. Armstrong, '09, is town engineer of Estevan, Sask, The information regarding him in the directory of last issue is incorrect.

ENGINEERING AND THE LAW

C. F. Elliott, B.A.Sc., '11.

When it was my pleasure as a student to attend the lectures given at the Engineering Society on various engineering topics, a great many speakers in their opening remarks on that profession maintained that the Beaver was the first engineer. Possibly the speaker was right, but it is my purpose to speak to you on that which is more ancient than, and in operation long before, the so-called first engineer, viz., The Law, an intangible but ever present something which has governed the world from the beginning, whether that beginning was according to God, the founder of all law, the Darwinian theory, or any other theory—there was always law—natural law, law of nations, lex non scripta, lex scripta, lex contracta, etc., but always law.

The law of which I speak is not that of contract but rather the rights, duties and obligations under which the engineer must work while performing the works called for in a contract. Rights, duties and obligations which the law under whatever name it may pass says shall be observed and obeyed.

Let us begin by supposing that an engineer is to excavate and construct on lot 2, a building, further supposing that he is owner as well as engineer. A contractor is then employed to perform the work, as drawn up, not stating at this moment whether the engineer gives him complete control of the whole work, or lets it in pieces, keeping direct control over it himself.

All subsequent remarks hereafter may be modified or provided for by written contract between the parties. This written contract usually contains an indemnity clause indemnifying the engineer and (or) owner from all loss, actions, etc., which might arise due to the carrying out of the work hereunder, and the contractor in turn usually insures himself against any loss, etc., with some insurance company, especially if it is a large work.

If I appear at times to wander away from the set of facts as given, it will be for the purpose of bringing out some point which might be of interest to some of you.

The lay of our property and adjoining properties is shown by the diagram. Lot 1 has a three story brick building on it which has been there for more than twenty years. Lot 3 is vacant.

Excavation must be commenced, therefore let our discussion be first with regard to

Support of Land by Land

Support of land exists in two ways.

(1) Lateral support.

(2) Subjacent support.

Lateral, when obtained from the earth of the adjoining lot; subjacent, when obtained from the underlying strata. But the law regarding both is precisely the same.

The owner of one lot of land is entitled to have it supported laterally by the land adjoining by way of natural easement; likewise,

where the surface rights are in one person and the mineral or subterranean rights in another, the former is entitled to have the surface kept at its natural and ancient level and the latter in excavating must give this support or suffer the consequences in an action for damages. An example will suffice. Humphries v. Brogden, in which the defendant, while excavating, even though carefully, let down the surface to the injury of the plaintiff, and it was held that the plaintiff was entitled to damages on the principal that the right to subjacent support was a right of property passing with the soil, and as I stated, this also is the principle with regard to lateral support.

Nevertheless it may be noted that while the owner of land is entitled to the support of the underlying strata he is not entitled to the support of subterrenean water, and you, as engineers, may drain your land, although the consequences may be to let down your neighbor's surface or the surface of any third person in the neighborhood. This was exemplified in a case where the defendant sank a shaft on his land, the effect being to divert the water which percolated through his land into that of the plaintiff's. Held, that the defendant had an absolute right to do what he did, and the court could not restrain him, even though his purpose was that alleged by the plaintiff, viz., to compel the plaintiff to buy his land, for a man may, without incurring liability, so use his own property as to cause damage to his neighbor, provided the damage be not done by illegal means.

Thus, one cannot by building a house near the margin of his land, prevent his neighbor from excavating his own land, although it may endanger the house, unless, of course, by lapse of time the adjoining land has become subject to a servitude.

The Support of Buildings by Land

The right of support of land laterally and subjacently does not extend to buildings erected upon the land as I have indicated above.

Rights of supports for buildings, if they can be established at all, must have their origin in a grant, expressed or implied. Where implied it will be either from circumstances surrounding the grant of land itself or from long and uninterrupted enjoyment of the right.

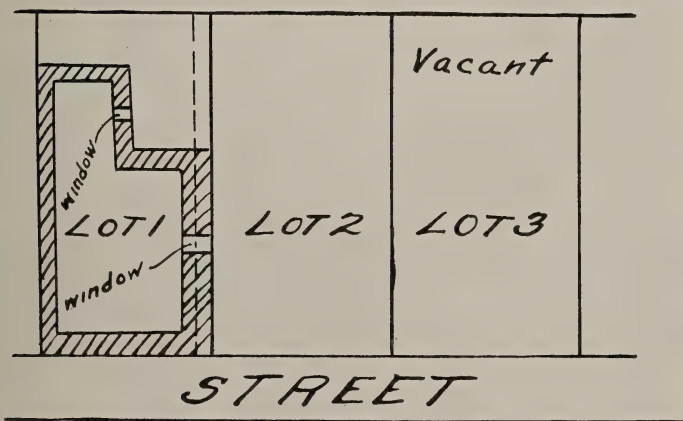
This user before it attains the sanctity of a grant must, under the prescription act, be for a full period of twenty years.

It may be here stated, as an implied circumstance, that as a general principle when land is purchased for a particular object, known to the vendor he will not be allowed to derogate from his own grant by so using his own property as to render impossible the accomplishment of the purchaser's purpose.

The law applicable to the support of the building on lot 1 by your land applies as well to the support of buildings by buildings; this was decided in the case of Lamater v. Davis, where it was held that when ancient buildings belonging to different owners adjoin each other, there is a mutual right of support from the adjoining building as well as from the land. It, however, may be here noted, that where the owner of a building has acquired no legal right of support for it, either from the soil, or from the buildings on the soil,

of his neighbor, the latter in dealing with his own land is not relieved from taking all reasonable care not to let down the former's building. He is bound in excavating his own land to support his neighbor's house by means of temporary props and by all other means ordinarily resorted to for such purposes, and, if on taking such care as a reasonable and prudent man would take, the land under the building does cave in, then, if it can be shown that it was due to the superimposed load or weight of the building, and that had the building not been there the soil would not have caved in, you would not be liable. The above raises a nice question in the theory of stability.

Let us now consider shortly the liability of owner and contractor. It often becomes a question whether the owner and contractor or



the contractor only, is liable for injury to an existing structure by reason of the building operations carried on upon the land adjoining i.e., upon lot 2 with reference to lot 1 and 3. When the owner places the work, which is lawful in itself, and which, if carried on without negligence, would not involve injury to the adjoining buildings, in the hands of a competent contractor, and divests himself of all control over the workmen and over the building operations after indicating to the contractor what is to be done, the liability for any injury caused will lie upon the contractor. The owner does not, in fact, render himself responsible for the negligence of the contractor or his workmen. This view was adopted in Allen v. Haywood, where the contractor had been employed by a navigation commissions to carry out certain works lawful in themselves, and in the course of his operations he improperly and without authority, introduced water into a drain which had been insufficiently made by himself, the result being that the plantiff's land was flooded. It was held that the contractors and not the owners were liable to the plantiff.

But where the work to be done, though lawful in itself, is likely in the course of execution to cause injury to adjoining premises, unless proper precautions are adopted by the contractors, then on

his failure to adopt sufficient precautions, the owner as well as the contractor will be liable for the injury caused to the adjoining buildings.

And further, where by statute, by-law or otherwise there is an absolute duty on the owner or his engineer to do the work or have it done in a particular way, if it is not so done he will be liable, even though the contractor to whom he delegated it was competent to carry it out properly. It largely depends upon the circumstances of each case and can in a large measure be ascertained before the work is commenced.

Let us now touch on the

Rights as to Water

Easements as to water can subsist only when it flows in a definite channel and not over water which percolates through the soil as the case of Bradford v. Pickles demonstrates, or putting it in another way, there is no right to the continued flow which runs through natural underground channels, undefined or unknown, and which can only be ascertained by excavation.

The subject, "water," has been classed with a great many other things which are termed dangerous, such as, electricity, fire, etc. And there is a liability for the breach of duty to prevent damage from dangerous things, and if you will allow me to digress for the moment, I will endeavor to show in some small measure what duty rests upon you in respect of water. All these dangerous things have to be handled at one time or another by the engineer and for purposes of illustrating the principles, it will be necessary to take examples from all kinds of work.

We may state as the first general principle that the person who, for his own purposes, brings on his land and collects and keeps there any dangerous thing likely to do mischief, if it escapes, must keep it in, properly protect it, and guard it at his peril, and if he does not do so, he is prima facia answerable for all the damage which is the natural consequence of its escape. However, he can excuse himself by showing that the escape was owing to the fault of some ascertainable third party or that the escape was the consequence of the act of God, or perhaps of the king's enemies. But it is no excuse that the escape was due to the act of a stranger; the rule does not apply where the person charged has not himself brought, collected, or kept the thing on the land, or where he has brought or collected and kept it not solely for his own purposes, but wholly or in part for the benefit of the person who is damaged by its escape. In any event the defendant is only liable for the natural consequences of the escape. A few examples will illustrate the above principles.

In the case of Rylands v. Fletcher, which is the leading authority on this subject, the plaintiff was the lessee of mines. The defendant was the owner of the mill, standing on land adjoining that under which the mines were worked. The defendant constructed a reservoir and employed competent persons to build it, and there was no evidence of negligence. The plaintiff had worked his mines up to a spot where there were certain old passages of a disused mine; these

passages were connected with vertical shafts communicating with the land above, which had also been out of use for years, and were apparently filled with marl and earth of the surrounding land and above which was constructed the reservoir. Shortly after the water had been introduced into the reservoir it broke through some of these old shafts and flowed thence into the plaintiff's mine. The gist of the action was the collecting of the water and **not keeping it from escaping,** and whether this was the result of negligence, or whether it was the result of a latent and undiscovered defect in the engineering works, was quite immaterial, and the defendants were liable.

In another case on this subject, the defendant was owner of a house which he had let out in floors to separate tenants. The different floors were supplied with water from a cistern at the top of the house. One of the supply pipes burst and the plaintiff's tenant in the basement was flooded. As the defendant had stored the water for the benefit of the plaintiff (along with the other tenants), he was not liable, in the absence of negligence, and the same rule applies where water was stored partly for the plaintiff's benefit and partly for the defendant's. The verdict in this case would have been different if the defendant had stored the water in this reservoir solely for his own purpose. He would then have been keeping it at his own peril. If you had been the engineer who put in the cistern and its connections the owner would undoubtedly endeavor to fix on you the blame for the damage done, especially if the cistern had been of recent construction. But this is departing a little too far from our plan, although, as I have said in the beginning, it was not my intention to adhere strictly to my sketch, but to endeavor to give you a few broad principles.

There is one more subject that might interest you and that is **party walls.**

Let us move the property line between lots 1 and 2 further to the west so as to have it situated exactly in the middle of the east wall of the building on lot 1, thereby making it a party wall, as shown by dotted line.

According to an eminent English judge, a party wall may mean:

(1) A wall of which the two adjoining owners are tenants in common. This is the most frequent kind of a party wall.

(2) Where the wall is divided longitudinally into two strips, one belonging to each of the neighboring owners.

(3) Where the wall belongs entirely to one of the adjoining owners, but is subject to an easement or right of the other to have it maintained as a dividing wall between the two tenements.

(4) Where the wall is divided longitudinally into two halves, each half being subject to a cross easement in favor of the owner of the other half. This would seem to arise where the wall was originally a party wall of the second kind and where the one has acquired by prescription a right of support from the other, just in the same way as any other building would gain a right of support from an adjoining building.

With regard to the first kind of party wall, it seems that it is

the kind which the court will always consider a party wall to be, when the only evidence regarding it is evidence of common user, and certainly when the deed describes it simply as a party wall. As to the rights of each tenant, either is entitled to a full enjoyment of all parts of the wall, and if one puts anything upon the wall which obstructs the others full enjoyment, the proper remedy is for that one to remove it himself, provided the removal can be peaceably made.

The second kind of party wall. The case of Matts v. Hokins, illustrates this. A and B put up a wall on the dividing property line. It was held that as it was known where each owner's land extended to, the wall was not the property in common of them both, but each owned absolutely the half which was built on his ground, and he may pare it off or build it higher, provided he does not interfere with the other owner's part.

With regard to the wall shown on the diagram (the property line moved as shewn), apart from any express deed you have the absolute right to notch into, rest upon and lean to in any manner you choose.

If you in building, on repairing the party wall so extends its foundations as to encroach on your neighbor's ground, this will constitute a trespass. The court, as a general rule, however, will not order its removal. But your neighbor, if he wants it removed, must do it himself as stated, but once the materials are affixed to your neighbor's soil, they become his. Your neighbor, however, is entitled to damages for trespass and usually the measure of such damages will be the probable expense of removing the encroachment.

This short summary touches all too lightly some of the salient and almost apparent principles in contact with which an engineer is likely to come.

You, as the jury before whom I place this short summary, must, before being able to come to any decision, return asking for more particulars as to each and every principle herein contained.

PRESENTATION TO MR. AND MRS. W. J. GRAHAM

The members of the staff at the "School" in some degree expressed their kind regard for Mr. Graham, when, on the evening of December 15, they presented Mr. and Mrs. Graham with a purse of gold. The presentation was made by Dean Galbraith, who expressed his pleasure at seeing Mr. Graham looking so well after thirty-six years of faithful service at the "Old Red School." Several other members of the staff spoke also, including Prof. Wright, Prof. Gillespie, and Prof. McGowan.

Mr. Graham won the friendship not only of the students but of the staff as well, and when the graduates return to visit the buildings, one of their first inquiries invariably is, "Where is "Prof.? I don't see him around."

Mr. Graham made a very appropriate reply on behalf of himself and Mrs. Graham. He had received many tokens of regard since he had left the "School" and he assured those present that he appreciated very much this mark of friendship.

TEST OF A RUSSELL-KNIGHT "28" ENGINE

PROF. H. W. PRICE, B.A.Sc., '01.

The following is a report by Prof. Price, on a test conducted, under his supervision, on a Russell-Knight "28" engine. The fact that this engine is wholly of Canadian manufacture, renders the very satisfactory results of the tests, especially pleasing to Canadians. [Ed.] The report is as follows:

To Russell Motor Car Co., Limited,
Toronto, Ont.

This report is to certify that the writer has tested a Russell-Knight "28" engine, manufactured by the Russell Motor Car Co., Limited, of Toronto, with the following results:

The Engine. Fig. 1 shows Russell-Knight "28" engine No. 2280 on the test stand as it appeared during the endurance run. The photograph was taken while the engine was under 42 h.p. load on its

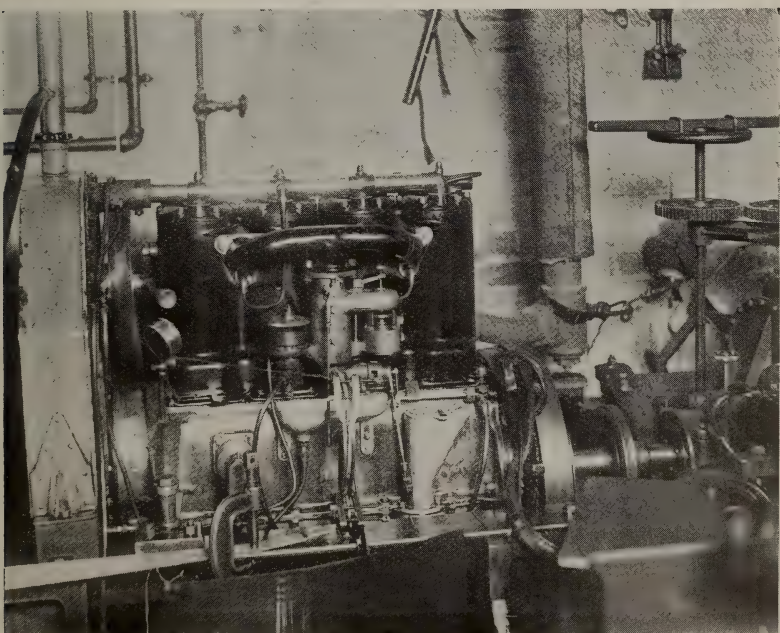


Fig. 1. Russell-Knight "28" Engine, No. 2280, photographed while under 42 h.p. load at 1200 r.p.m.

24 hour run at 1200 r.p.m. The engine has four cylinders, 4 1-8 in. bore, 5½ in. stroke. The A. L. A. M. rating for these dimensions is 27.2 h.p. The Russell flywheel electric starter and generator, and flexible joint between engine and transmission were included. The

engine and accessories were stock equipment as regularly furnished in Russell cars.

Carbureter. Stromberg type D, 1¾ in., fixed jet, spring tension on auxiliary air and jet adjusted as usual for stock engines. The setting of the carbureter was not changed during the whole period of endurance and one-hour tests.

Ignition. Regular equipment, Mea type BK4 magneto and ordinary wire-point spark plugs. The spark lead was set for best operation at each speed until standard maximum lead was obtained.

Fuel and Oil. The gasoline and oil were from the ordinary supplies used for test cars. The gasoline averaged 65 degrees Beaume at 60 degrees F. The oil was comparatively light in body, and not special for this test.

Observers and Observations. The Russell Motor Car Co. gave the writer authority to direct and control the test in any manner

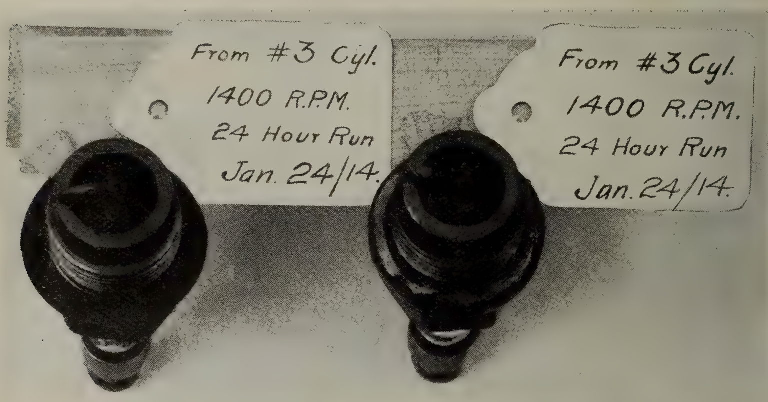


Fig. 11. Showing condition of exhausted spark plugs which explained decrease of power in 1300 and 1400 r.p.m. runs.

desired. Two shifts of three men attended to the brake adjustment, supplies of fuel and oil, and general assistance. Three observers were arranged in three shifts, so that the engine was continuously watched throughout the test.

The brake was of balanced hydraulic reaction type, controlled as to torque by water adjustment. Speeds were set by a carefully calibrated tachometer. For holding speed an auxiliary tachometer was belted to an extension of the brake shaft. One man's duty was to continuously control brake water supply to hold speed at required value.

Observations were made of torque and actual speed every ten minutes, and hourly of gasoline gauge, jacket water temperatures inlet and outlet, oil temperature, oil pressure on bearings, exhaust pressure, and room temperature. Oil and gasoline supplies were noted as required.

Gasoline was measured by a Bowser pump, and temperature

noted of outflowing gasoline so that these volumetric measurements could be correctly reduced to 60 degrees F. The pump was carefully calibrated.

Results

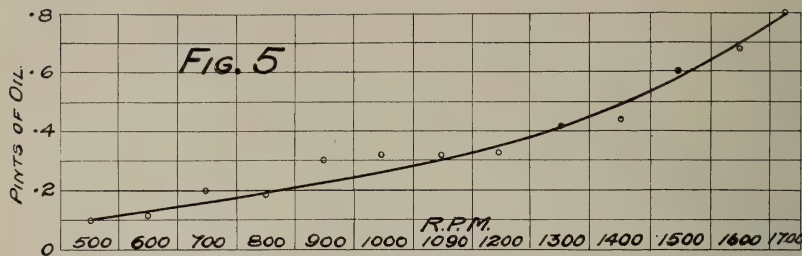
The engine ran continuously * for 300 hours with throttle wide open, with no adjustment of any description to the engine or any of its parts. The magneto was not adjusted except for spark advance once at the commencement of each new speed up to 1100 r.p.m., when maximum advance was reached. The settings of gasoline jet and auxiliary air spring were not examined or adjusted throughout the whole run. Some spark plugs were renewed when the higher speeds were reached as explained below.

The work included 24 hours each at 500 r.p.m., 600, 700, 800, 900, 1000, 1090 (giving rated piston speed 1000 ft. per min.), 1200, 1300, 1400, 1500, 1600, and 12 hours at 1700 r.p.m., total 300 hours. The total quantity of gasoline consumed was 7771 pounds, or 1082 imperial gallons, or 1299 U. S. gallons. The total oil consumed was 54.8 gallons. The total work done by the engine was 10680 brake horse-power hours. The average horse-power during this work covering all speeds from 500 to 1700 r.p.m. is $\frac{1}{300}$ of 10680 or 35.6 h.p. The average gasoline consumption for all speeds was .727 pounds per brake horse-power hour. Curves showing details of this test are given in Figs. 2, 3, 4, 5.

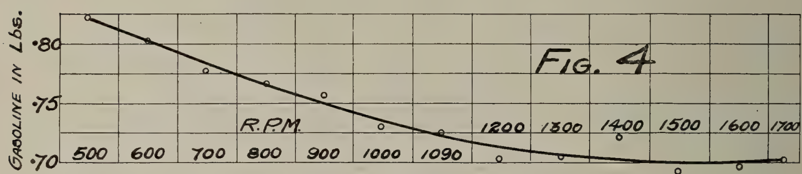
The belt on the radiator fan carried its load with no adjustment, and only a moderate loss of tension. The circulation pump drove the water through the jackets and radiator so that at no time did the outlet water rise more than 22 deg. F. above inlet temperature. The outlet temperature was held around 140 deg. F. during the test by withdrawing hot water from and supplying cold water to the top of the radiator.

Lubrication. Lubrication of the engine was carefully observed. It will be noted from the results that this engine went through the test with very much less oil per brake horse-power hour, or per gallon of gasoline consumer, than any other engine of either poppet or sleeve-valve type on official record. Each day throughout the test oil was fed into the intake for a ten-minute period to see whether or not the upper end of the sleeves would run more freely, but no difference could be detected. Examination of the sleeves after the test revealed beautifully run-in surfaces with no mark suggesting lack of lubrication. The exhaust gases were free of oil smoke, and were practically invisible during the test. The oil was maintained at a mean temperature of about 140 deg. F. It was necessary to water-cool the bottom of the oil pan to hold the temperature down to 140 deg. during the higher speeds when the engine was developing 45 to 58 h.p. At times the temperature went as high as 154 deg. F. for short intervals.

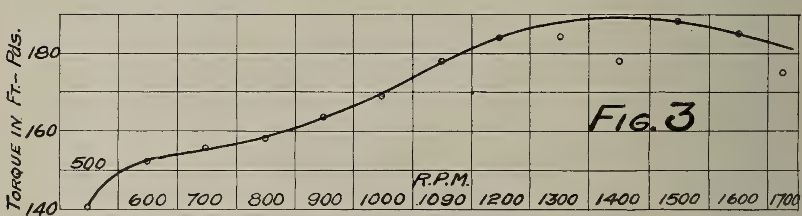
This engine demonstrated that it could lubricate perfectly with a remarkably small quantity of oil while enduring the hardest work of which it was capable for much longer periods than could possible be arranged in actual service.



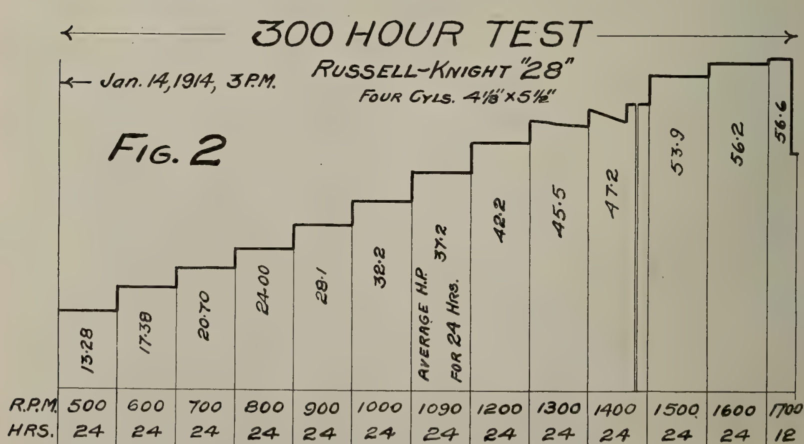
Pints of Oil Consumed per Gallon of Gasoline Consumed



Pounds of Gasoline per B.H.Hr.



Engine Torque in Pounds at One Foot Radius.

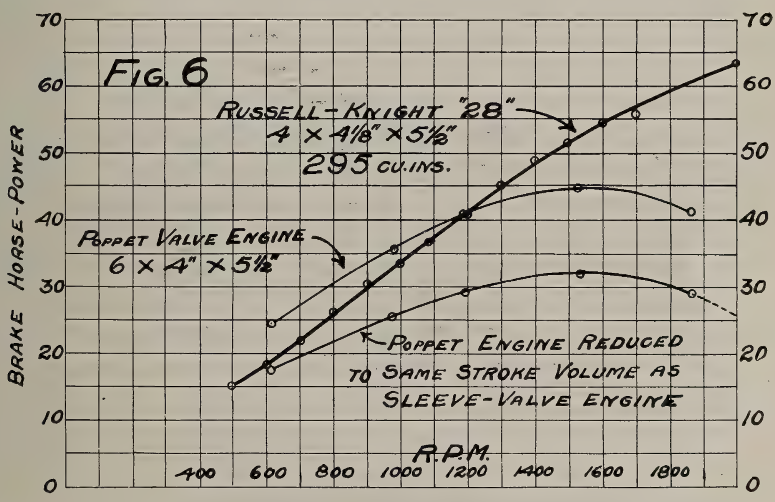


Step Chart Showing Average B.H.P. During Each Day

Performance Curves of 300 Hour Run

Fig. 2 is a step chart representing the power developed and work done in 24 hour intervals. The total work in the 300 hours was 10680 brake horse-power hours, giving an average output for all speeds of 35.6 h.p., or 31 percent above A.L.A.M. rating 27.2 h.p. Each period is marked with the average power developed at the corresponding speed. The horse-power rose to 1700 r.p.m. practically in proportion to engine speed.

One run was made at 1090 r.p.m. to obtain a 24-hour result at a piston speed of 1000 feet per minute, to which speed the A.L.A.M. rating 27.2 h.p. directly applies. For this period the engine delivered an average of 37.2 h.p., 36.75 percent. above its rating. This result was obtained with exhaust against a back pressure of 3.5 pounds per sq. in. The chart shows that the rated 27.2 h.p. is developed at about 840 r.p.m. instead of 1090 r.p.m. Up to the end of the 1090



COMPARATIVE B.H.P. CAPACITIES AT VARIOUS SPEEDS

r.p.m. run, exhaust was let through the roof via a 20-foot 3-inch pipe having a 90 deg. T turn at the bottom, two 45 deg. elbows farther up, and a standard car muffler at the top. For higher speeds the muffler was removed.

During the 1300 r.p.m. run a slight but gradual reduction of power was noted for which no satisfactory explanation was apparent. At 1400 r.p.m. the effect became more noticeable. After 15 hours at that speed cylinder No. 3 missed a few times. The spark plug was immediately replaced. Fig. 11 shows the condition of the plug removed. The central electrode was burned off down to the porcelain. Plug in No. 2 was then also replaced. Fig. 11 shows its condition with a spark gap of 3-8 inch. After removal of these exhausted plugs the power immediately rose from 45.8 to 49.75 h.p. The averages given for the 1300 and 1400 r.p.m. periods are

from actual powers with defective plugs. No allowance was made for what might have been recorded with plugs in good condition. Removal of the plugs involved no relief for the engine as the operator made each exchange in 40 seconds while the man on the brake held speed at 1400 r.p.m. with throttle wide open. At higher speeds it was necessary to replace several more plugs having elongated spark gaps. No allowances were made for power variations due to exhausted spark plugs.

* During the 19th hour in the 1400 r.p.m. test the only shutdown occurred, and from no fault of the engine. The factory has a modern sprinkler system. One sprinkler head was eight inches from the exhaust pipe at the roof outlet above the engine. The heat of the exhaust pipe caused the sprinkler head to blow out, and water

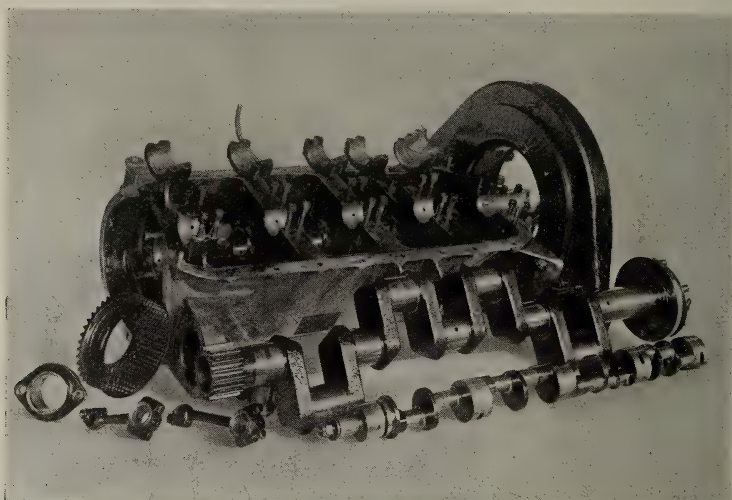


Fig. 12. Showing condition of crank and eccentric shafts, bearings, sleeve rods, chain gears, etc., after tests.

came in a flood over engine, men, and records. Before a cover could be thrown over the engine, the ignition short-circuited causing the stop. It required 15 minutes to shut off the water supply and drain the system in four floors above the test room. Then the flywheel starter was used, and whirled the engine at 180 r.p.m., but no spark was available. With removal of a teaspoonful of water from the safety gap cup on the magneto, ignition trouble disappeared. Then the engine refused to run for lack of gasoline. Water in a small chamber under the float bowl was finally located as the difficulty, correction of which was made without removal of the carbureter and with no alteration of adjustments. The total time loss of 51 minutes covering water soaking and gasoline stoppage was compensated by delaying the end of the run 51 minutes. It was feared that the sudden downpour of cold water on the engine working with exhaust

manifold at a dull red heat would do serious damage. Instead, the engine finished the day in splendid form, and during the next 24 hours at 1500 r.p.m. made the best record up to that time. At the 297th hour, 1700 r.p.m., cylinder No. 2 developed distress and dropped out of service. The cause was located later on and is stated below. The engine was held at 1700 r.p.m. on three cylinders by reducing torque of the brake, and developed 41 h.p. during the remaining three hours of the run, or 71 percent. of the power being developed by the four cylinders at the same speed.

A tubular record of all results of the 300-hour run is offered below. It shows 12-hour averages of observations:

Table of 300 Hour Run

Hours From	Hours To	Averages R.p.m.	Averages B.h.m.	Gasoline, lbs. Per B.h.p.-hr.	Pints of Oil Per Gal. Gas.
0 to	12	500	12.95	.822	.096
12	24	500	13.61		
24	36	600	17.33	.802	.104
36	48	600	17.41		
48	60	698	20.38	.780	.120
60	72	698	21.02		
72	84	795	23.76	.769	.192
84	96	801	24.24		
96	108	901	27.65	.756	.304
108	120	905	28.55		
120	132	1003	31.96	.735	.320
132	144	1001	32.44		
144	156	1093	37.09	.725	.320
156	168	1093	37.31		
168	180	1203	41.93	.702	.324
180	192	1205	42.47		
192	204	1304	46.00	.706	.420
204	216	1302	45.00		
216	228	1401	46.94	.720	.440
228	240	1401	47.75		
240	252	1499	53.64	.693	.600
252	264	1501	54.10		
264	276	1600	56.50	.698	.680
276	288	1602	55.90		
288	300	1700	52.60	.701	.800

One-hour Trials. Immediately after the conclusion of the 300-hour run, cylinder No. 2 was examined. It was found that the top ring in the head had chipped and caught the top of the inner sleeve, breaking a piece out of it, so that compression was destroyed, and the cylinder had dropped out of service. New sleeves and head were put in this cylinder, and the engine immediately started on a series of one-hour runs at 500, 600, 700, 800, 900, 1000, 1100, 1200, 1300, 1400, 1500, 1600, 1700 r.p.m., and five minutes at 2000 r.p.m. The carbureter settings were left exactly as in the 300-hour run. The results are detailed in a table below, and are plotted in heavy line curves in Figs. 6 and 7.

Results of One-hour Test Runs

Speed	Horse-power	Torque
502.5 r.p.m.	15.02. h.p.	157. ft. pds.
597.	18.25	161.
699.	21.7	163.
800.	26.0	170.7
903.	30.2	175.6
999.	33.5	176.
1100.	37.0	176.5
1203.	40.75	178.
1300.	45.0	182.
1400.	49.0	183.
1502.	51.5	180.
1600.	54.6	179.
1700.	55.7	172.
2000.	63.5	167.

The horse-power curve shows power rising more than proportionately to speed up to 1400 r.p.m., just as in the 300-hour test. It shows 63.5 h.p. at 2000 r.p.m. It shows that the maximum horse-power would not be reached before 2500 to 2700 r.p.m. Obviously this engine showed no lack of ability to take and use a full charge of mixture at 2000 r.p.m. The power at 2000 r.p.m. was 233 percent of rated horse-power.

The torque curve, Fig. 7, shows torque at 2000 r.p.m. and at 700 r.p.m. to be identical. It shows no sign of the bend in Fig. 3 between 500 and 600 r.p.m. which substantiates a statement made later that horse-power and torque for the first 24-hour run were low because of the initial extra friction of a new stock engine.

Outstanding Features of Results

1. Maximum power, 300-hour, continuous run without adjustment, repair, or replacement save to spark plugs.

2. A.L.A.M. rating developed at 840 r.p.m. instead of 1090 r.p.m. with muffler on and a back pressure of about 2 pounds per square inch.

3. At rated speed 1090 r.p.m. developed 37.2 h.p., or 36.75

percent. over rated 27.2 h.p. with muffler on and a back pressure of 3.5 pounds per sq. in.

4. At every speed except 1300 r.p.m. (where spark plug difficulties prevented) the power during the second half of a 24-hour run was greater than in the first half.

5. Averaged for all speeds from 500 to 1700 r.p.m. an output of 35.6 h.p., 31 percent above its A.L.A.M. rating.

6. Averaged **double** its rated horse-power, or 54.4 h.p., for the last 72 hours of the 300 hours, viz: ½ day at 1700, 1 day each at 1600 and 1500, and ½ day at 1400 r.p.m.

7. Developed at 2000 r.p.m. 63.5 h.p., or 233 percent. of its rated horse-power.

8. When tested for idling, this engine idled as quietly at

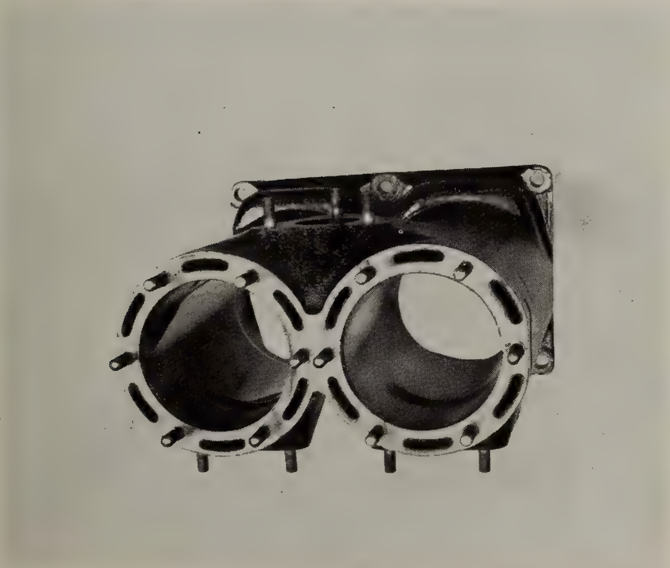


Fig. 13. Showing condition of cylinder walls after tests.

180 r.p.m. as it ran steadily when pulling 56 h.p. at 1600 r.p.m., with no change in carbureter adjustments. It was remarkably quiet and free from vibration at all speeds and loads.

9. The torque (see Fig. 3) rose sharply during the first 24 hours work, showing that when started on the test it had the extra initial friction of a new stock engine. Torque rose with speed to 1400 r.p.m., then dropped only slowly with further increase in speed.

10. Gasoline and oil consumptions (see Figs. 4 and 5) are unique. The gasoline economy is excellent at 500 r.p.m., and is beyond all previous records known to the writer for automobile engines of equal stroke volume at 1500, 1600, and 1700 r.p.m.

Condition of Parts

After completion of all tests the starter was tried. It whirled the engine quite as usual. The engine was idled at 180 r.p.m. with no change from previous carbureter settings, and ran beautifully at that low speed. The air pump for tires and gasoline tank pressure pumped quickly to 300 pounds per square in. at 180 r.p.m., showing that valves and piston fitted perfectly. There was a fracture in the oil pan on one side above the oil level. The oil pump which had held about 50 pounds per sq. in. on the bearings through all the tests showed the same high pressure. Hence the pump was in good condition and no bearings were loose.

The engine was then completely pulled down in presence of the writer. Figs. 12, 13, 14, 15, 16, afford some idea of the excellent condition of the parts. The pistons, sleeves, and cylinders were round and true, and showed polish marks of perfect fitting. The

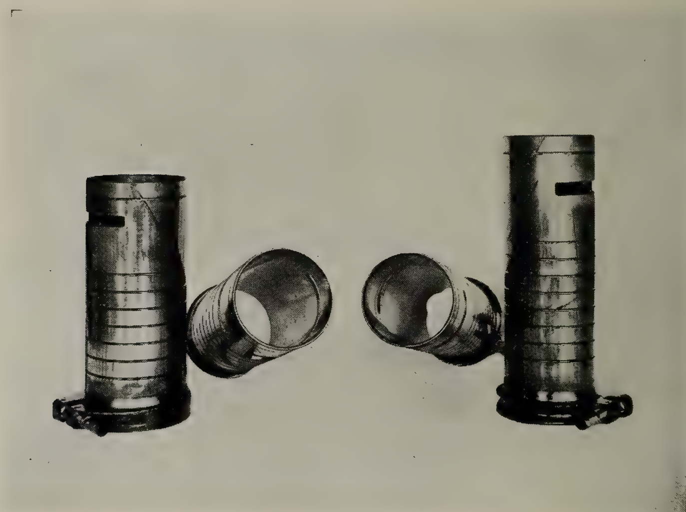


Fig. 14. Showing condition of the inner and outer sleeves after tests. Polish marks show that the sleeves remained both straight and round.

exhaust ports in the cylinders were clear and clean. The exhaust ports in the sleeves showed about 1-32 inch carbon deposit on the edges, The piston heads had a slight carbon deposit around the edges, but tool marks were visible elsewhere. The cylinder heads were quite clean, small pieces of crust being in evidence here and there. The broad junk rings were beautifully bedded to the sleeve walls. The bearings of crank shaft, eccentric shaft, rods, and wrist pins were snug, and quite ready for use in car service. Most of the bearings bore an attractive polish. The chain drive for the sleeves was slightly loose, but not in need of adjustment. Altogether the engine was quite ready to undergo a second similar test.

Stock Motor

The writer, unknown to the management, looked over the records of all departments from engine assembly to finish test to obtain the history of this particular engine. He then visited the cost department and was given the time slips of all the men who worked on it. The information gathered from the foremen checked exactly with the cost records, and proved beyond doubt that engine No. 2280 was a stock engine in every respect. In fact, it was sent from the block test to the silence room for these tests without having been pulled down for examination after block testing, which inspection is given to every stock engine.

The routine history of factory procedure, and the detail history

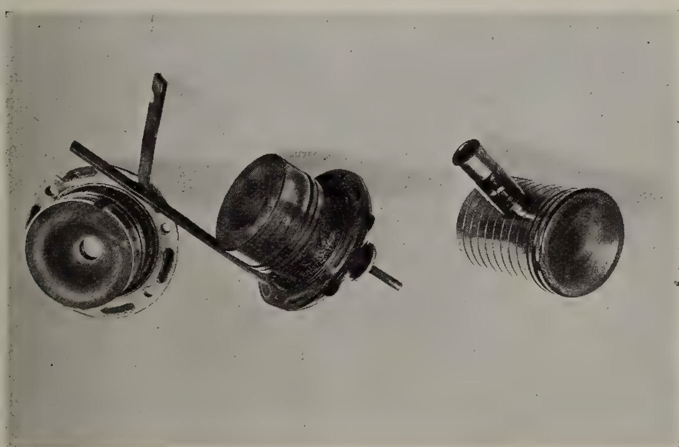


Fig. 15. Showing the piston, wrist bearings and cylinder heads. The piston and cylinder heads are practically without carbon deposit.

of this engine, together with various other information not of general interest, are included in an appendix to this report.

Character of Usual Tests

Endurance tests have usually been made at speeds giving approximately 1000 ft. per min. piston speed. Published tests of this kind demonstrate ability to endure long periods of hard work at one speed. They do not exhibit the properties of an engine when working at maximum output for long periods at all speeds covered by ordinary use of the engine.

Another feature of moderate speed tests is their failure to cause relatively great continued mechanical punishment of working parts. For example, it is well known that stresses due to reversal of motion of reciprocating parts increases not as the speed, but as the square of the speed. With this fact in mind, we may compare the testing value of 24-hour runs with wide-open throttle at 1000 r.p.m. and at say 1600 r.p.m.

(1) Revolutions in 24 hours at 1000 r.p.m., 1,440,000. At 1600, 60 percent. more, or 2,304,000 revolutions. This sleeve-valve engine will give equal or slightly greater torque (see curves) at 1600 than at 1000 r.p.m. Hence in 24 hours the engine

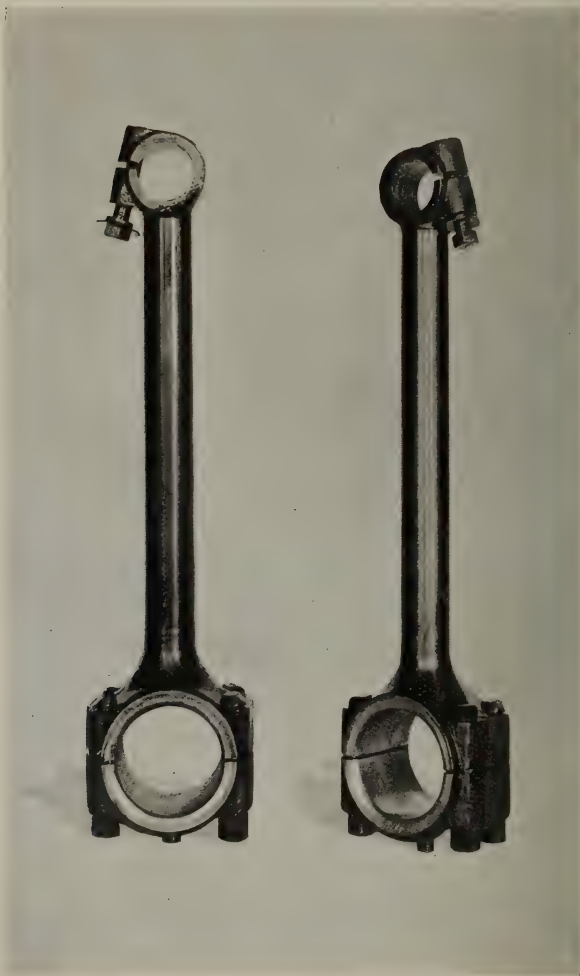


Fig. 16. Showing connecting rods and lower-end bearings. These rods are tubular.

will do at least 60 percent. more work at 1600 than at 1000 r.p.m.

(2) Inertia stresses at 1000 r.p.m. might be represented by say 100. At 1600 r.p.m. these stresses become 100 by $\frac{1600 \times 1600}{1000 \times 1000}$ equals 256, or 2.56 times the stresses at 1000 r.p.m. This ratio applies to each and every stroke in the 24 hours, hence

to 60 percent. more strokes at the higher speed. Hence the net increase in mechanical straining is 2.56 x 1.6 or 4.1 times that at 1000 r.p.m.

The 1600 r.p.m. test therefore means obliging the engine to do 60 percent more work in the 24 hours while subjected to 4.1 times the mechanical straining received in the same time at 1000 r.p.m

These ideas assist one to realize the sort of hard work engine No. 2280 went through in the 300-hour test, especially as the heaviest burdens were borne at the end and not at the beginning of the test.

Comparisons

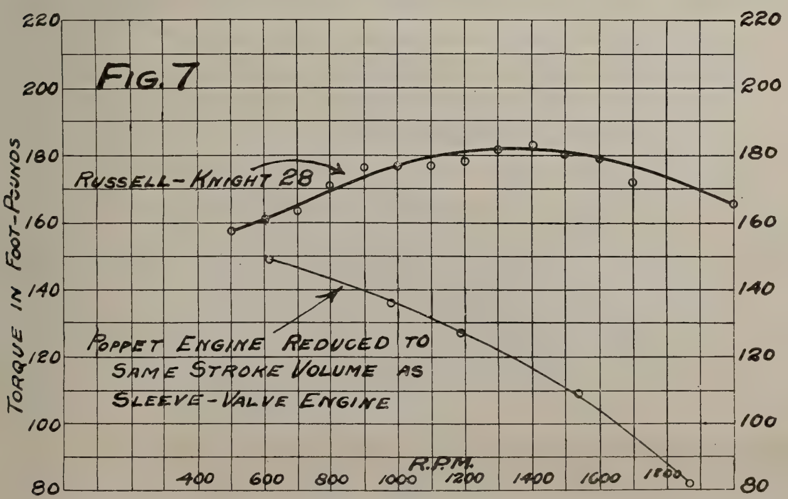
At your request the writer has made some comparisons of the performance of this sleeve-valve engine with the only official record of a poppet-valve engine with a somewhat similar test. The test referred to was made by the Automobile Club of America, New York City, and the results have been before the public since May, 1913.

The engines are of different dimensions:

	Cylinders	Bore	Stroke	Stroke Volume	Relative Size
Poppet-Valve Engine....	6	4″	5½″	416 cu. ins.	1.41
Sleeve-Valve Engine....	4	4 1-8″	5½″	295 cu. ins.	1.00

Relative A.L.A.M. ratings are 38.4 and 27.2 respectively, in direct proportion to their sizes. In the comparisons the writer has reduced the results for the poppet-valve engine in the ratio 1.41 to 1.00 in order to obtain relative performances of two types having equal stroke volume. This method of comparison is fair because it credits the poppet engine of reduced size with the same thermal and mechanical efficiencies as an engine of the same type 41 percent. larger.

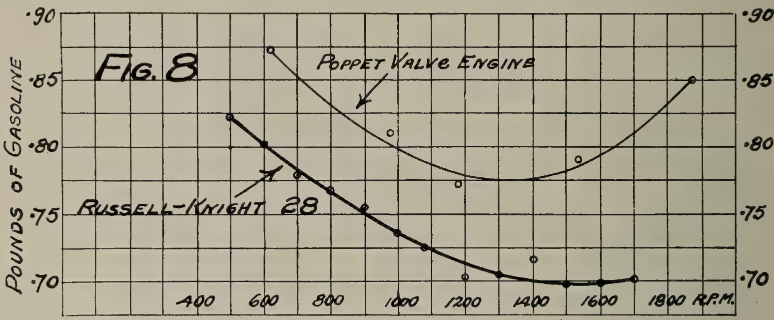
Curves in Figs. 6, 7, 8, 9, 10 show comparisons in graphical form. Below are tabulated some of the comparative performances:



COMPARATIVE TORQUES AT VARIOUS SPEEDS

Torque or Turning Effort

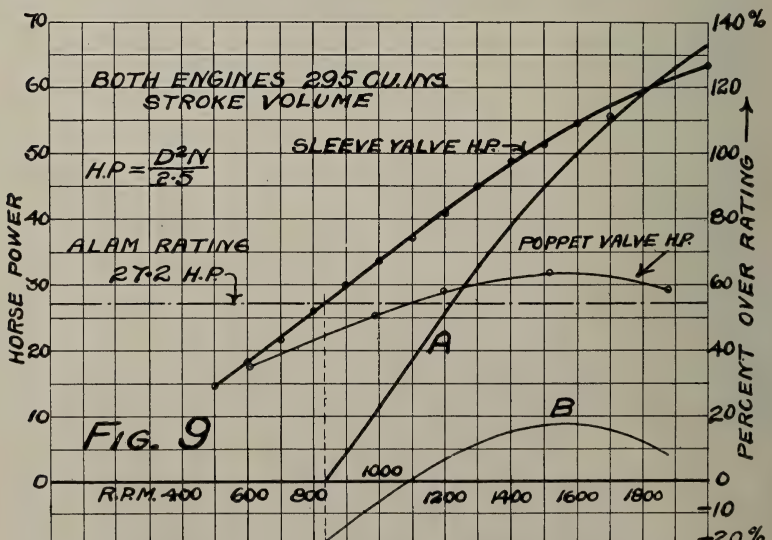
Speed	Poppet-valve Torque	Sleeve-valve Torque	Excess over Poppet-valve
612 r.p.m.	149.7 ft. pds.	161.2 ft. pds.	7.7 percent.
970	137.	175.6	28.1
1191	127.3	180.8	42.
1533	108.9	180.	65.2
1870	82.	170.6	108.



COMPARATIVE GASOLINE PER B.H.P.-HR. AT VARIOUS SPEEDS

Gasoline Economy See Fig. 8
Pounds per B.H.P.-Hr.

Speed	Poppet-valve	Sleeve-valve	Percent. better than Poppet-valve
612 r.p.m.	.871 lb.	.799 lb.	8.2 percent.
1000	.798	.735	7.9
1300	.775	.706	7.7
1500	.782	.695	11.2
1700	.810	.701	13.5

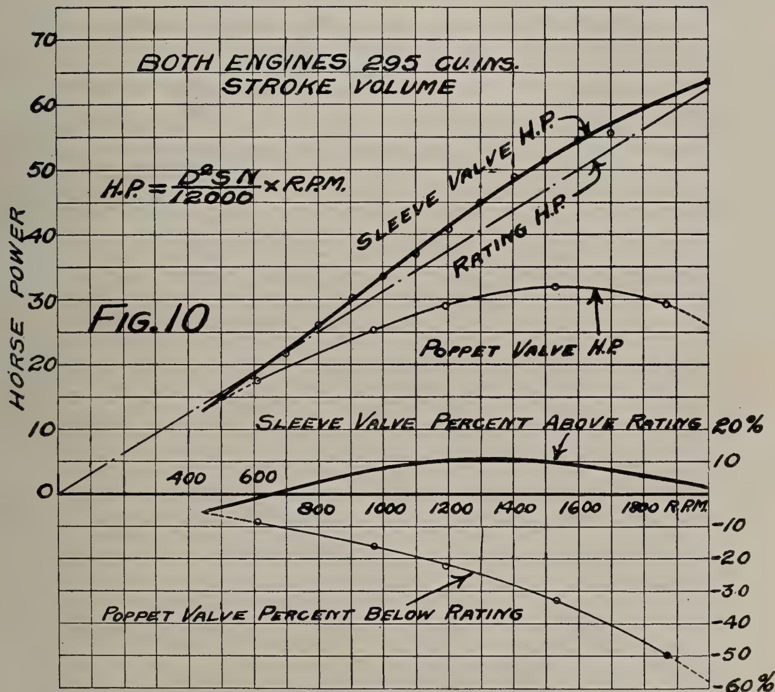


COMPARISON WITH ALAM RATING AT VARIOUS SPEEDS

Percent over rating Sleeve Valve — Curve A
Poppet Valve — Curve B

Horse-Power With Regard to A.L.A.M. Rating

Speed	H.P. Sleeve-valve	Percent. Rating	H.P. Poppet-valve	Percent. Rating
840 r.p.m.	27.2 h.p.	100 percent.	22.2 h.p.	81.5 percent.
1090	37.2	136.7	27.2	100.
1533	52.4	192.8	31.85	117.
2000	63.5	233.	26.	95.5



COMPARISON WITH DENDY MARSHALL-SPEIGHT FORMULA
For Maximum H.P. at Various Speeds

Horse-Power With Regard to Dendy Marshall-Speight Formula

Speed	H.P. Sleeve	Percent. Rating	Rating	H.P. Poppet	Percent. Rating
612 r.p.m.	18.8 h.p.	97.8%	19.21 h.p.	17.45 h.p.	90.8%
657	22.5	100.	22.5	18.4	81.7
1300	45.	111.	40.55	30.4	74.9
1533	52.4	109.3	47.85	31.85	66.5
2000	63.5	101.6	62.4	26.	41.6

WHAT OUR GRADUATES ARE DOING

H. L. Roblin, B.A.Sc., is assistant engineer in the Cranbrook office of the Water Right branch of the British Columbia government.

C. W. B. Richardson, B.A.Sc., '07, has been for about four years with the Dominion Bridge Co. Limited, Montreal. His address is 61 Riverside Drive, Lachine Locks, Que.

W. H. Sutherland, B.A.Sc., '02, is assistant chief engineer of the Montreal Water & Power Co., Montreal, Que. His residence is 384 Grosvenor Ave., Westmount, Que.

J. N. Wilson, B.A.Sc., '06, is with the Hydro Electric Power Commission of the Province of Ontario at Toronto, Ont.

G. S. Stewart, '07, is sales engineer for the Canadian General Electric Co. Limited, at Montreal, Que.

A. R. MacPherson, B.A.Sc., '13, is at Guelph with P. H. Secord & Sons Limited, contractors of Brantford and Guelph.

E. A. Kelly, '11, is resident engineer at Winnipeg, for the Can. Pac. Railway between Winnipeg, Boissevain, Lauder and Neptune.

J. G. MacLaurin, B.A.Sc., '11, is with the water Power Department of the Algoma Steel Corporation, Sault Ste. Marie, Ont.

A. S. Cook, B.A.Sc., '11, is associated with the Geo. R. Cook Co., contracting engineers, 1012-1013 Ford Building, Detroit. He is at present located in Alpena, Michigan, superintending the contract for building the foundations for a large limestone crushing plant.

J. G. Mackinnon, '09, is resident engineer on the C.N.R. main line at Albreda Summit, Rocky Mountains. His P.O. address is Henningville, B.C.

F. G. Marriott, B.A.Sc., '03, is chemist and engineer of tests at the Department of Works, foot of Prince's St., Toronto.

G. E. Silvester, '91, is chief engineer for the Canadian Copper Co., Copper Cliff, Ont.

V. A. Newhall, B.A. Sc. '10, is with the Canadian Inspection and Testing Laboratories, Limited, Edmonton, Alta.

H. L. Leadman, '11, E. B. MacColl, '11, and F. R. Mortimer, B.A.Sc., '10, are in the Department of Naval Service, Hydrographic Survey, Department of Interior, Ottawa.

K. F. Mickleborough, B.A.Sc., '13, is assistant engineer in the Superintending Engineer's office, Department of Railways and Canals, Cornwall, Ont.

H. P. Frid, '11, is superintendent, of the Frid-Lewis Co., Limited, consulting engineers and contractors, Winnipeg, Man.

J. Lanning, B.A.Sc. is superintending the operations of the cintering plant for the Mond Nickel Co., Limited, Coniston, Ont.

M. Liebermann, B.A.Sc., '11, is in the Irrigation branch, Department of Interior, Calgary, Alta.

C. J. Marani, '88, has a private practice as consulting structural engineer at Anacortes, Wash. He is also Pacific coast manager for the Russia Cement Co. of Anacortes, covering from the boundary line to San Francisco, including Seattle, Tacoma, Portland, etc.

APPLIED SCIENCE

INCORPORATED WITH

Transactions of the University of Toronto Engineering Society

DEVOTED TO THE INTERESTS OF ENGINEERING, ARCHITECTURE AND APPLIED CHEMISTRY AT THE UNIVERSITY OF TORONTO

Published every month in the year by the University of Toronto Engineering Society

SUBSCRIPTION RATES

Per year, in advance	$2.00
Single copies	.20

Advertising rates on application

Address all communications:

Applied Science,

Engineering Bldg., University of Toronto,

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EDITORIAL

At the request of a number of the graduates we are inserting in each copy of Applied Science this month, a half-tone portrait of Prof. Bain, whose biography appeared in the January issue. Professor Bain is one of the Associate Editors of the Journal, and it is to him that it owes its name "Applied Science." The name was suggested by him when, in 1907, it was changed from the Transactions of the University of Toronto Engineering Society." The gradurtes we know will appreciate this opportunity of receiving a portrait of Professor Bain, who has won an enviable place in the minds and hearts of each of them.

THE ENGINEERING SOCIETY DANCE

Since the Annual Dance was first inaugurated by Mr. A. D. Campbell and his executive, it has always stood out as the most brilliant social function at the University. Each year the At-Home has vied with its predecessors in affording an evening of most delightful enjoyment for the members of the Society and the guests present, but the committee this year are to be congratulated upon having outshone all former efforts in this respect. The free and congenial spirit which pervaded the assemblage, and which is characteristic of all "School" functions, furnished the key to the real success of the Dance. Everyone enjoyed themselves and endeavored to make everyone else enjoy themselves. The arrangements of the committee were so well planned and so nicely executed that no possibility of improvement suggested itself.

Columbus Hall was beautifully decorated with the colors of the "School." The wall lights were each trimmed with a Union Jack, a Science pennant and a Canadian ensign. The orchestra on the platform was almost obscured from view with a bower of palms, while in the background of the stage was suspended a large shield bearing the crest of the Engineering Society, relieved against a festoon of University colors, artistically arranged.

The happy faces of 120 couples, the pretty gowns and excellent music, added all that could be desired to render this the most brilliant and enjoyable function of the season. The patronesses were Lady Gibson, Mrs. Falconer, Mrs. Galbraith, Mrs. C. H. C. Wright, Mrs. H. E. T. Haultain, and Mrs. A. T. Laing. The guests were received by Mrs. Falconer, carrying a bouquet of Killarney roses presented by the students, Mrs. Wright and Mrs. Laing. Supper was served at quartette tables after the eighth dance and was on a par with the excellence of everything else that contributed toward the success of the evening.

Among the graduates present were the following: Messrs. C. F. Von Gunten, '13; T. V. McCarthy, '13; W. A. Spellman, '13; A. V. DeLaporte, '10; C. H. Cunningham, '11; P. G. Cherry,'11; H. H. Madill, '11; J. S. Galbraith, '13; C. F. Elliott, '11; W. J. T. Wright, '11; T. R. Loudon, '05; J. Roy Cockburn, '01; C. B. Hamilton, '06; A. T. Laing, 92; and Prof. C. H. C. Wright, '88, of Toronto; also Messrs. A. R. MacPherson, '13, of Guelph; Roy G. Sneath, '11, of Thorold; F. F. Foote, '13, of Merritton; A. G. Gray, '13, of Niagara Falls, and D. B. Cole, '11, of Copper Cliff.

TORONTO BRANCH OF CANADIAN SOCIETY OF CIVIL ENGINEERS

The Toronto Branch of the Canadian Society of Civil Engineers had luncheon at McConkey's on Wednesday, February 11th. About ninety members were present and a most successful meeting was held, the result of the energetic efforts of the secretary, Mr. J. S. Galbraith, and the other members of the committee. If this, the first meeting of the year, is to be taken as an indication of future activities, the

Toronto Branch of the Society bids well to have a year of marked progress.

After the opening remarks by Mr. C. H. Mitchell, who acted as chairman in the absence of Mr. A. F. Stewart, chief engineer of the Canadian Northern Railway, Mr. J. M. Clark, K.C., spoke for a short while on the relation of the engineer to the law. The engineer is becoming a more prominent factor in legal proceedings, but his relation to the court is very different to that of the lawyer. The engineer who is retained on a case should not display too great zeal for his employer, for he owes a duty to the court and to his profession to present the engineering phases of the points under discussion in an unprejudiced and truly professional way.

Dean Galbraith also spoke, expressing his pleasure at seeing so many present at the first meeting of the year. He was glad to see so many student members present and hoped that a greater number would soon become associated with the Society as student members so that they might become more familiar with the work which the Toronto Branch is doing and also reap the benefits thereof.

Professor C. R. Young, on behalf of the library committee, outlined the plans of that committee for the improvement and extension of the usefulness of the library. He stated that there are in the Engineers' Club Rooms at the present time four separate small technical libraries, which, for various reasons, are more or less useless as they now exist. It was the ideal of the committee as it is of the Engineers' Club, to bring about a unificatoin of these libraries into a large and valuable central technical library accessible to any one who is a member of at least one of the technical organizations contributing to it. Unfortunately, the energies of the Engineers' Club directorate were so much taken up with the problem of securing new quarters at the present time that little could be expected of it in the matter of library improvement for a year or two. However, the Canadian Society of Civil Engineers could do a great deal independently that would in no way interfere with what the Club might do, but would be complementary to it.

The first duty of the library committee, the speaker asserted, was to place upon the shelves bound volumes of indispensable periodicals, especially the proceedings and transactions of the great engineering and technical societies. While in doing this, duplication of sets now accessible in the city should generally be avoided, there were series of such great importnace to the engineer that the placing of them in the library of the Canadian Society of Civil Engineers would be a real service to all those who will use the central technical library. It was the policy of the library committee, also, to secure a number of series of reports issued by governments, commissions, cities and experiment stations, regardless of duplication. These could now be secured at a very small outlay, while in a few years they might be out of print and not procurable at any cost.

Professor Young stated that a determined effort was being made to obtain the opinion of representative members of the branch in the matter of the books to be added to the library. A considerable

number were being asked to send in lists of the ten most useful books to the practicing engineer in the special field of the member consulted. Not only the opinions of the members of the committee would thus be represented in the final choice of books but also the best judgment of many specialists.

Several schemes for extending the usefulness of the library were outlined by the speaker. When the catalogue is complete it is proposed to regularly draw the attention of the members to the library by some means, possibly by the issuing of a monthly bulletin containing a statement of the accessions to the library during the previous month, requests for information or gifts of books, reports or periodicals, acknowledgment of contributions or of information supplied, and any other matter which would stimulate an interest in the library. The committee felt that some arrangement should be made, too, by which members could take books away from the library for a limited period. It was the opinion of the speaker that the double purpose of extending the usefulness of the library and of increasing the student membership of the Society might be furthered by drawing the attention of Engineering students in the University of Toronto to the value of the library to them particulary in connection with the thesis work of the fourth year. Professor Young also stated that exchange privileges were being sought with several other libraries in the city, by which a member could secure books from them with a minimum of trouble. A catalogue of the books in such libraries likely to be of interest to the practicing engineer would be kept in the Engineers' Club rooms.

On Feb. 25, at 8 p.m., Mr. C. N. Monsarrat, Chairman and Chief Engineer of the Quebec Bridge Commission gave an excellent illustrated lecture in the Chemistry and Mining Building of the University on "The Foundations of the New Quebec Bridge," before the Toronto Branch of the Society. An exceptionally large number attended and the executive are to be congratulated on the success of the meeting.

SCHOOL DEFEATS QUEENS AT REGINA

Score 5 to 1

At the amphitheatre rink, Regina, on February 14, a team of "School" graduates defeated a team picked from graduates of the various faculties of Queen's University.

The game was closely contested, but both teams played clean hockey as indicated by the fact that no penalties were meted out to either team. The score of five to one is a true indication of the play, into which the winners entered with the characteristic enthusiasm of "School" men.

The School of Science team lined up as follows:

Goal, A. P. Linton, '06; Point, H. R. Mackenzie, '13; Cover point, J. McD. Patton, '11; Rover, W. A. Begg, '05; Centre, O. F. Coumans, '11; Right, F. N. Read, '11; Left, E. W. Murray, '07: Spare, Stewart Young, '11.

DIRECTORY OF THE ALUMNI

Berkeley, G. L., '11, is assistant engineer in the Surveys Department for the Toronto Harbor Commission.

Berry, E. W., '10, is on Dominion land survey work, Department of the Interior, Ottawa. He is a D.L.S. man.

Bertram, G. M., '01, is manager of the Joplin, Mo., branch of the Sullivan Machinery Co., manufacturers of mining and quarrying equipment.

Betts, H. H., '06, is in Rio de Janeiro, Brazil, for the Rio de Janeiro Tramway, Light & Power Co.

Beynon, D. E., '06, is general superintendent of the Dunlop Tire & Rubber Goods Co., Toronto, as superintendent.

Billings, J. H., '11, is instructor in mechanical engineering in the University of Missouri, Columbia, Miss.

Bingham, H. C., '10, is engineer and land surveyor, New Grayson Bldg., Moose Jaw, Sask.

Binns, R. E., '13, is with the Pearl Lake Mine, Timmins, Ont.

Birchard, E. R., '09, is in the employ of the Russell Motor Car Co., West Toronto, in the transmission gear department.

Bissett, D. C., '10, is engineer for the Dome Mines, Porcupine, Ont.

Bissett, G. W., '06, is mill superintendent for the Canadian Exploration Co., Limited, at Naughton, Ont.

Bissett, J. R., '11, is in the Water Power Branch of the Department of the Interior, Ottawa.

Bitzer, A. M., '09, is in Montreal. We do not know at what he is engaged.

Black, B. S., '13. His address is 197 Madison Ave., Toronto.

Black, G. E., '08, is with the Ontario Government as roadway engineer.

Black, R. G., '95, is a member of the Toronto Hydro-Electric Commission.

Black, W. D., '09, is superintendent of the eastern branch of the Otis-Fensom Elevator Co., with headquarters in Montreal.

Blackwell, R. H. H., '10, formerly resident engineer for the Canadian Northern Ry. at Biscotasing, Ont., is now at Peterboro, Ont.

Blackwood, A. E., '95, is manager of the New York office of the Sullivan Machinery Co.

Blackwood, W. C., '06, is instructor in physics, Technical High School, Toronto.

Blain, D., '13, is draftsman for the Canada Foundry Co., Toronto.

Blair, W. J., '02. We do not know his present address.

Bleakley, J. F., '85, is engaged in a general engineering practice at Bowmanville, Ont.

Blizard, D. C., '09, is with the Toronto Structural Steel Co. at their works at Weston, Ont.

Boeckh, J. C., '06, is in Toronto, and is with the Boeckh Brush Co. as a member of the firm.

Bonnell, M. B., '04, whose home is in Bobcaygeon, Ont., has no business address with us at present.

Bouter, E. R., '13, his home is at Trenton, Ont. He is at present with the Canadian Crocker-Wheeler Co. at Montreal.

Boswell, E. J., '95, is on the engineering staff of the Canadian Pacific Railway Co., with residence in Toronto.

Boswell, M. C., '00, is lecturer in organic chemistry, University of Toronto.

Boswell, W. O., '11, is in electro-chemical work. His home address is 25 Roxborough St. W., Toronto.

Boulton, W. J., '09, is engaged in civil engineering and surveying in the West. His permanent address is Wallaceburg, Ont.

Bourne, O. B., '07, we do not know his address.

Boustead, W. E., '90, deceased.

Bow, J. A., '97, is in Great Falls, Mont., with the Boston & Montana Mining & Smelting Co.

Bowen, G. H., '09, has an office in this city as mechanical and electrical engineer and also patent attorney.

Bowers, W. J., '01, deceased, December, '06.

Bowes, H. F., '08, is superintendent of the Warren Bituminous Paving Co., Toronto.

Bowman, A. M., '86, was a member of the Pennsylvania Contracting Co., Pittsburgh, when last heard from.

Bowman, E. P., '10. His home is in West Montrose, Ont. We do not know his professional activities.

Bowman, F., '11, is with the Dominion Bridge Company in the office at Lachine, Que.

Bowman, F. M., '90, is vice-president and director of the Blau Steel Construction Co., Pittsburgh, Pa.

Bowman, H. D., '07, his present address is E. D., Y.M.C.A., 179 Marcy Ave., Brooklyn, N.Y.

Bowman, H. J., '85, is a member of

the firm of Bowman & Connor, consulting municipal and structural engineers, Toronto and Berlin, Ont. Mr. Bowman is engineer for the county of Waterloo.

Boyd, D. G., '94, is in Toronto, in the Department of Lands and Mines, Parliament Buildings.

Boyd, W. H., '98, is in Ottawa, topographical branch, Geological Survey, Department of the Interior.

Brace, J. H., '08, his address is 23 Lorne Ave., St. Lambert, Que. He is with the Bell Telephone Co.

Brackenreid, T. W., '11, is in the employ of the Canadian General Electric Co., in Peterborough, Ont.

Brady, W. S., '07, is manager of the Madison theatre on Bloor St. W., Toronto.

Brandon, E. T. J., '01, is assistant engineer for the Hydro-Electric Power Commission, Toronto.

Brandon, H. E., '06, is chief engineer of the Vulcan Iron Works, Winnipeg, Man.

Bray, L. T., '00, of Amherstburg, Ont., has a practice as land surveyor.

Brebner, G., '85, deceased, Feb. 21 '07.

Brecken, P. R., '08, is secretary of the Broadview Branch of Toronto Y.M.C.A.

Brereton, L. R., '13. We do not know his address.

Brereton, W. P., '01, is in Winnipeg, Man., with a consulting engineering practice.

Breslove, J., '03. We do not know his present address. He was in the steam turbine department of the Westinghouse Machine Co., Pittsburg, when last heard from.

Brian, M. E., '06, is city engineer of Windsor, Ont., and also engineer for several adjacent townships.

Bristol, W. M., '05, is in the Halifax, N.S., office of the Canadian Westinghouse Co.

Broadfoot, F. C., '06. His address is 142 Hastings St., Vancouver, B.C. He is a member of the firm McKenzie, Broadfoot and Johnston, Vancouver.

Brock, A. F., '10, is with the Canadian Copper Co., at Copper Cliff, Ont.

Brock, W. M., '11, is draftsman with the Canadian Bridge Co., Walkerville, Ont.

Brodie, W. M., '95, was with the Green Engineering Co., Pittsburgh, Pa., when we last heard of him.

Broughton, G. H., '07, is manager of the Steel Protector and Auto Tire Co., Vancouver, B.C.

Broughton, J. T., '01, is chief engineer of the Scotdale Foundry & Machine Co., Scotdale, Pa.

Brouse, W. H. D., '11, is in this city, with Kerry & Chace, Limited.

Brown, J. M., '02, was in the steam turbine department of the Westinghouse department of the Westinghouse Machine Co., Pittsburg, when we last heard from him. We do not know his present address.

Brown, T. W., '06, is a member of the firm Brown and Loucks, engineers and surveyors, Saskatoon, Sask.

Brown, D. B., '88, who was, when last heard from, locating engineer, Grand Trunk Pacific, is on our list of unknown addresses.

Brown, G. L., '93, resides in Morrisburg, Ont., and is engaged in civil engineering and surveying.

Brown, L. L., '95, is vice-president of the Foundation Company, Woolworth Building, New York.

Brown, T. D., '04, is in Calgary, Alta., western representative for the Canadian Fairbanks-Morse Co.

Brown, J. A., '07, is engineer in charge for the Trussed Concrete Steel Co., Vancouver, B.C.

Brown, E. I., '08, is in the sales dept. of the Northern Electric and Manufacturing.

Brown, C. E., '09, is in Hamilton, Ont., with the Canadian Westinghouse Company.

Brown, H., '11. His address is not on our fyles.

Browne, E. W., '09, His present address is unknown to us.

Browne, M. O., '10. His address is 313 McClellan Ave., Detroit.

Bryce, W. F. M., '08, is in the office of the city engineer. Ottawa Ont.

Buchan, P. H., '08, is assistant engineer, construction department, British Columbia Electric Railway, Vancouver.

Buchanan, J. A., '09, is on survey work at Edmonton, Alta. His address is 140 Jasper St. W., Edmonton.

Buchanan, T. R., '13, is in the mines surveying department of the Canadian Copper Co., Copper Cliff, Ont.

Buchanan, W. B., '13, is demonstrator in the department of electrical engineering at University of Toronto.

Burke, M. A., '09, deceased.

Bucke, W. A., '94, is manager of the Toronto district office of the Canadian General Electric Co.

Bunnell, A. E. K., '06, is engineer in charge of the construction on the Lake

Erie & Northern Railway, from Brantford to Galt.

Burd, J. H., '03, is engaged in survey work in Saskatoon, Sask. His address is P.O. Box 690.

Burgess, E. L., '03, is with the topographical surveys branch, Department of the Interior, Ottawa.

Burgess, J. R., '10, is inspector at the plant of the Algoma Steel Co., Sault Ste. Marie, for the Robert W. Hunt Co.

Burley, R. J., '04, is in the Irrigation office, Department of Interior, Calgary.

Burns, D., '83, deceased, July 27, '13.

Burns, J. C., '87, deceased.

Burns, J. E., '09, is a member of the firm "Langruel and Burns, Advertisers' Agents," Dineen Building, Toronto.

Burnham, F. W., '04, is in the engineering department of the Canadian Westinghouse Co., Hamilton.

Burnham, N. G., H., '10, deceased.

Burnside, J. T., '99. We do not know his address.

Burwash, L. T., '96, has an agency in Winnipeg, for a manufacturing firm.

Burrows, B. H. A., '13, is in charge of the Coleman Fare Box Co., at Tottenham, Ont.

Burwash, N. A., '03, is with Speight and Van Nostrand, surveyors and engineers, Toronto.

Bush, C. E., '07, is in Toronto. We do not know at what he is engaged.

Byam, F. M., '06, is in the employ of McGregor & McIntyre, Toronto, as chief engineer.

C

Cain, E. T., '11, is in the Bridge Dept., I. C. Ry., Moncton, N.B.

Calder, J. W., '04, is with the Hydro-Electric Power Commission at Port Arthur and Fort William, Ont.

Cale, W. C., '10, is with the Stone and Webster Engineering Corporation, as engineer on transmission line construction, at Keokuk, Iowa.

Caldwell, W. B., '13, is engaged in the Temiskaming District. We have not his present address.

Cameron, N. C., '04, is associated with the Dominion Engineering and Construction Co., of Montreal.

Cameron, A., '06, is in Winnipeg, Man., in the employ of the Vulcan Iron Works, Limited.

Cameron, M. G., '09, has no address with us at present.

Cameron, C. S., '11, has Beaverton, Ont., for his home address.

Cameron, O. L., '13, is engaged on pitometer survey work for the city of Toronto.

Campbell, A. D., '10, is in Cobalt, Ont., as mining engineer for the O'Brien Mines.

Campbell, A. J., '04. His home in Collingwood, Ont. We do not know the nature of the work upon which he is employed.

Campbell, A. M., '04, was, until recently, in Chilliwack, B. C. His address has changed recently, and we cannot supply it.

Campbell, L. L., '13, has Orangeville, Ont., as his permanent address. We do not know where he is at present.

Campbell, W. G., '02, who resides in Toronto, is engaged in railway contracting.

Campbell, A. R., '02. We have no address at present.

Campbell, R. J., '95. We do not know his address.

Campbell, G. M., '96, is superintendent of the power apparatus shops of the Western Electric Co., at Riverside, Ill.

Campbell, W. C., '05, whose home is at Keene, Ontario, is in the West, engaged in mining engineering.

Campbell, N. A., '08, is with the General Supplies Limited, 122 11th Ave. W., Calgary, Alta.

Campbell, R. A., '09, is in the employ of the Tagona Light and Power Co., at Sault Ste. Marie, Ont.

Campbell, A. W., '06, is in with the Hydro-Electric Power Commission, Toronto.

Campbell, J. E., '08, has no address with us at present, except his home address at Coldstream, Ont.

Campbell, C. D., '11, is town engineer of Galt, Ontario.

Canniff, C. M., '88, is in Toronto with 90 King W. as his business address.

Carey, B., '89, has no address with us at present.

Carlyle, W. M., '10, is secretary-treasurer of Carlyle and Beck, concrete contractors, Toronto.

Carmichael, C. G., '02, deceased.

Carmichael, R. M., '13. His home address is Kenora, Ont.

Carpenter, H. S., '97, is superintendent of Highways of the Province of Saskatchewan, Department of Public Works, Regina.

Carrie, G. M., '13, is resident engineer for Chipman & Power, Neepawa, Man.

Carroll, A. M., '08, is a member of

the engineering staff of Routly & Summers, Haileybury, Ont.

Carroll, M. J., '06, is with the Department of the Interior, Ottawa, in the Topographical Survey Branch.

Carscallen, H. R., '08, is on hydrographic work in the West, with P. M. Sauder, at Calgary.

Carson, W. R., '05, is mechanical engineer in charge of plant and construction, Grasselli Chemical Co., Cleveland, O.

Carter, W. E. H., '98, is a member of the firm of consulting mining engineers, Carter and Smith, Toronto.

Caster, J. H., '07, is with the Hydro-Electric Power Commission, Toronto.

Caudwell, N. S., '10, is taking a course in law at Osgoode Hall.

Cavell, E., '07. His address is 182 Sunnyside Ave., Toronto.

Chace, W. G., '01, a member of the firm of Kerry and Chace, Limited, Toronto, is chief engineer of the Greater Winnipeg Water District, Winnipeg, Man.

Chadwick, R. E. C., '06, is with the Foundation Company, Limited, Montreal.

Chadwick, W. W., '11, resides in Hamilton, Ont. We are not informed as to how he is employed.

Challen, G., '08. His address is Chedoke, P.O., Hamilton, Ont.

Challies, J. B., '04, is superintendent Water Power Branch, Department of the Interior, Ottawa.

Chalmers, W. J., '89, is assistant engineer Ohio River Improvement, U. S. Government, and resides at Vanport, Pa.

Chalmers, J., '94, is city commissioner, Edmonton, Alta.

Chandler, R. B., '11, is assistant city engineer, Saskatoon, Sask.

Charlesworth, L. C., '93, resides in Edmonton, and is director of Surveys for the Province of Alberta.

Charlton, H. W., '97, is on the ataff of the Experimental Farm, Ottawa, as chemist.

Charlton, O. W. N., '11, is in the water Power Branch, Dept. of Interior, Ottawa.

Chase, A.V.,'05. We do not know his address or occupation.

Cherry, P. G., '11, is advertising salesmanager, Might Directories Limited, Toronto.

Chestnut, A. W., '10, is in the office of the surveyor-general, Vancouver, B.C.

Chestnut, E. F., '11, is also in Vancouver.

Chestnut, F. H., '08, is at Port Mann B. C., with the Canadian Northern Pacific Railway.

Chestnut, V. S., '09, is engaged in engineering work in British Columbia. His home is in Vancouver.

Chewett, H. J., '88, is in England at the present time. His permanent address is Prince George Hotel, Toronto.

Chilver, C. A., '04, is with the Canadian Bridge Co., at Walkerville, Ont.

Chilver, H. L., '04, is assistant city engineer, Windsor, Ont.

Chisholm, D. C., '10. We do not know in what line of work he is engaged. He is in Winnipeg, Man.

Christie, W., '02, is engaged in engineering and land surveying at Prince Albert, Sask.

Christie, A. G., '01, is assistant professor of steam engineering, University of Wisconsin, Madison, Wis.

Christie, F., '06, is with the Algoma Central Railway in charge of construction.

Christie, U. W., '04, is in Ottawa, Ont., in the Astronomical Survey Branch, Department of the Interior.

Chubbuck, L. B., '99, is with the Canadian Westinghouse Co., Hamilton Ont., in the engineering department.

Clark, F. W., '11, is at Niagara Falls, N.Y. He is in the employ of the International Waterways Commission.

Clark, G. T., '06, until recently city engineer, Saskatoon, Sask., is now general manager of Western Pavers, Limited.

Clark, H. J., '11. His address is 197 Westminster Ave., Toronto.

Clark, H. S., '10, is instrument man on the new Welland Ship Canal, at Port Dalhousie, Ont.

Clark, H. A., '13, is with the C. P. Ry. at Wayland, Ont.

Clark, J., '00, was, when last heard from, with the P. & L. E. R. R. at Pittsburg, Pa., as electrician. We do not know his present address or occupation.

Clarke, F. F., '03, is divisional engineer for the Canadian Northern Railway Co. His home is in the city.

Clarke, J. E., '11. His home address is 139 Dowling Ave., Toronto.

Clarkson, G. E., '13, is engaged in England. We do not know his address.

Claveau, J. A., '10, Chicoutini Pulp Co., at Chicoutini, P.Q.

Cleary, F. S., '11. His home is in Windsor, Ont. We have no other address for him at present.